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(54) **Filling interstices between pieces of material**

(57) Apparatus for filling the interstices 9a, 22 between irregular-shaped pieces of material such as aggregate 9 or nuclear or toxic waste 21 with a cementitious mixture in a mould comprises a vibrating table 3 for receiving a mould 2. An eccentric weight vibrator 6 is mounted on the underside of the table 3 and produces a vibratory motion about a vertical axis. The vibratory motion may be either an oscillating or a rotational motion. The frequency of vibration used is at or near to the natural or harmonic frequency of the cementitious material being moulded.

The method and apparatus when applied to aggregate provides a finished article of high structural strength. In the case of nuclear or toxic industrial waste a fully filled and hence stable drum which retards leaching of waste products is provided.

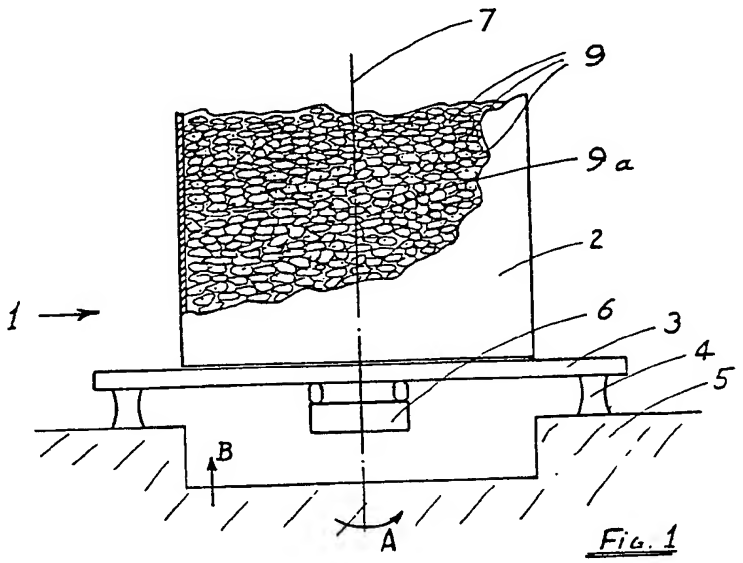

Fig. 1

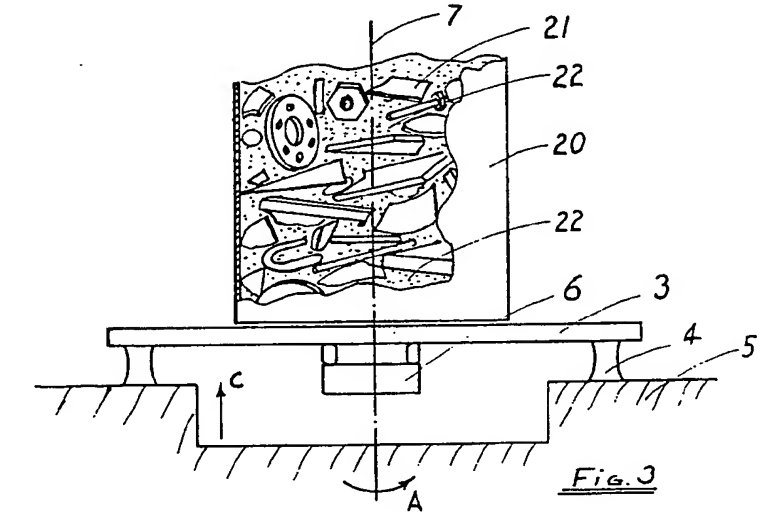

Fig. 3

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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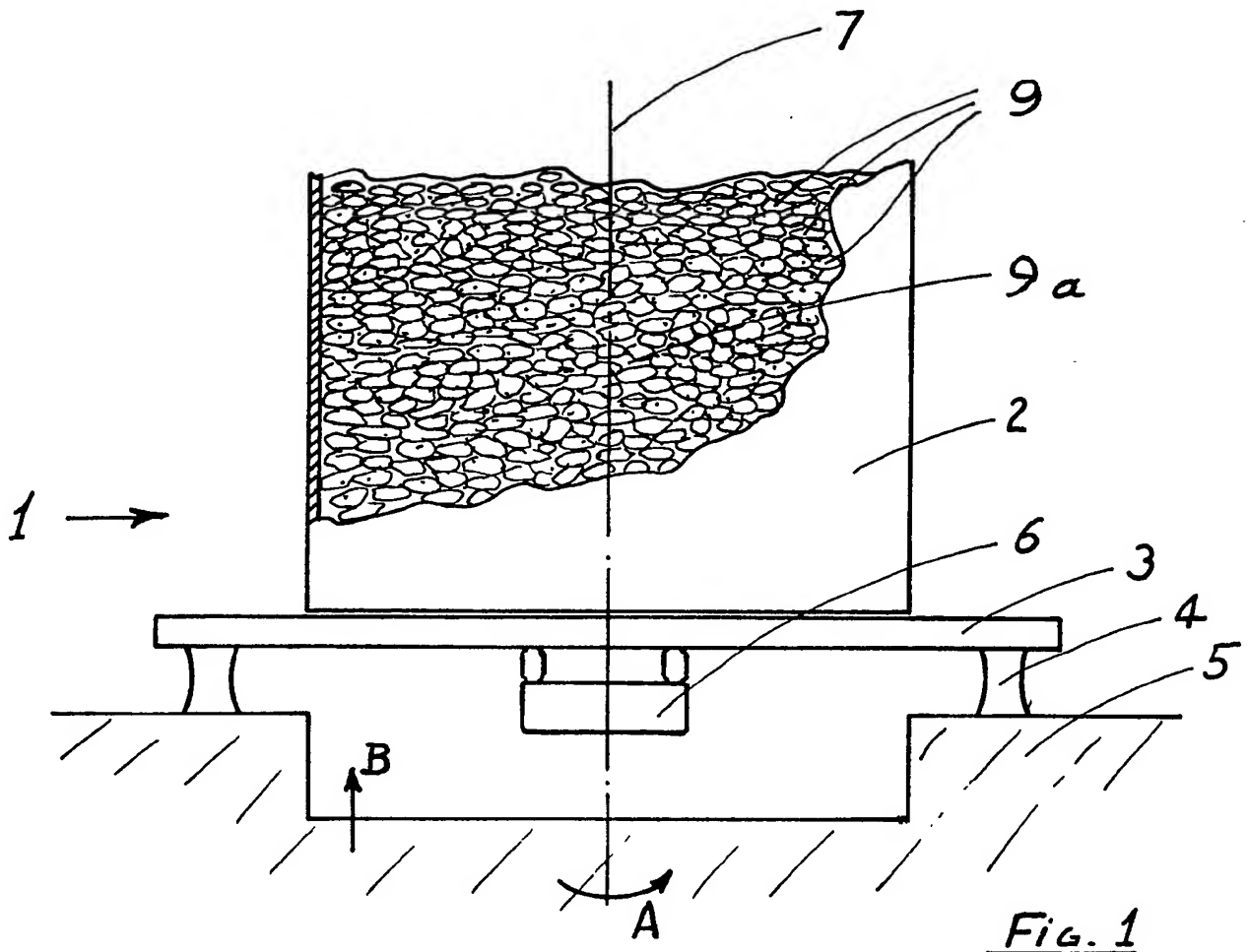

Fig. 1

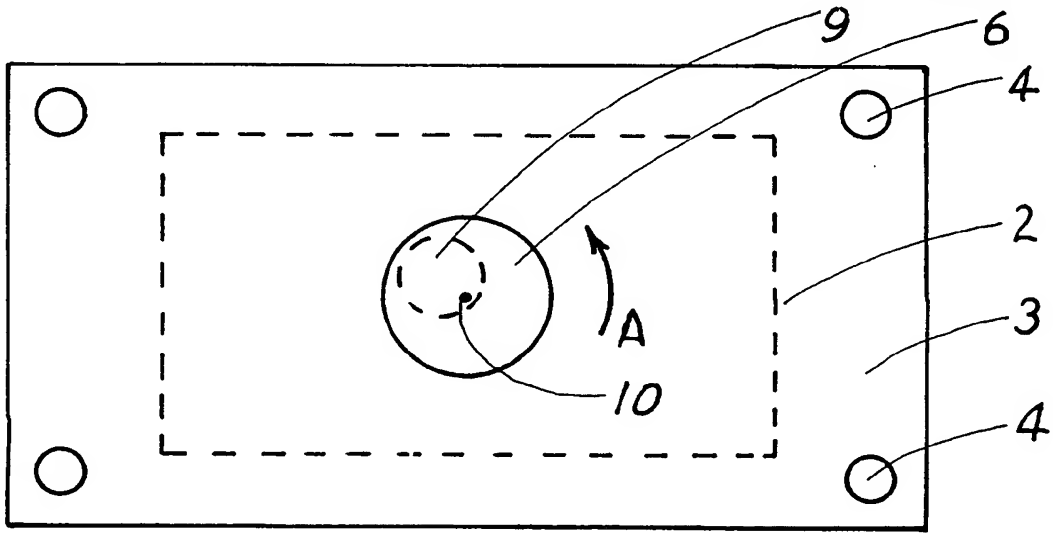

Fig. 2

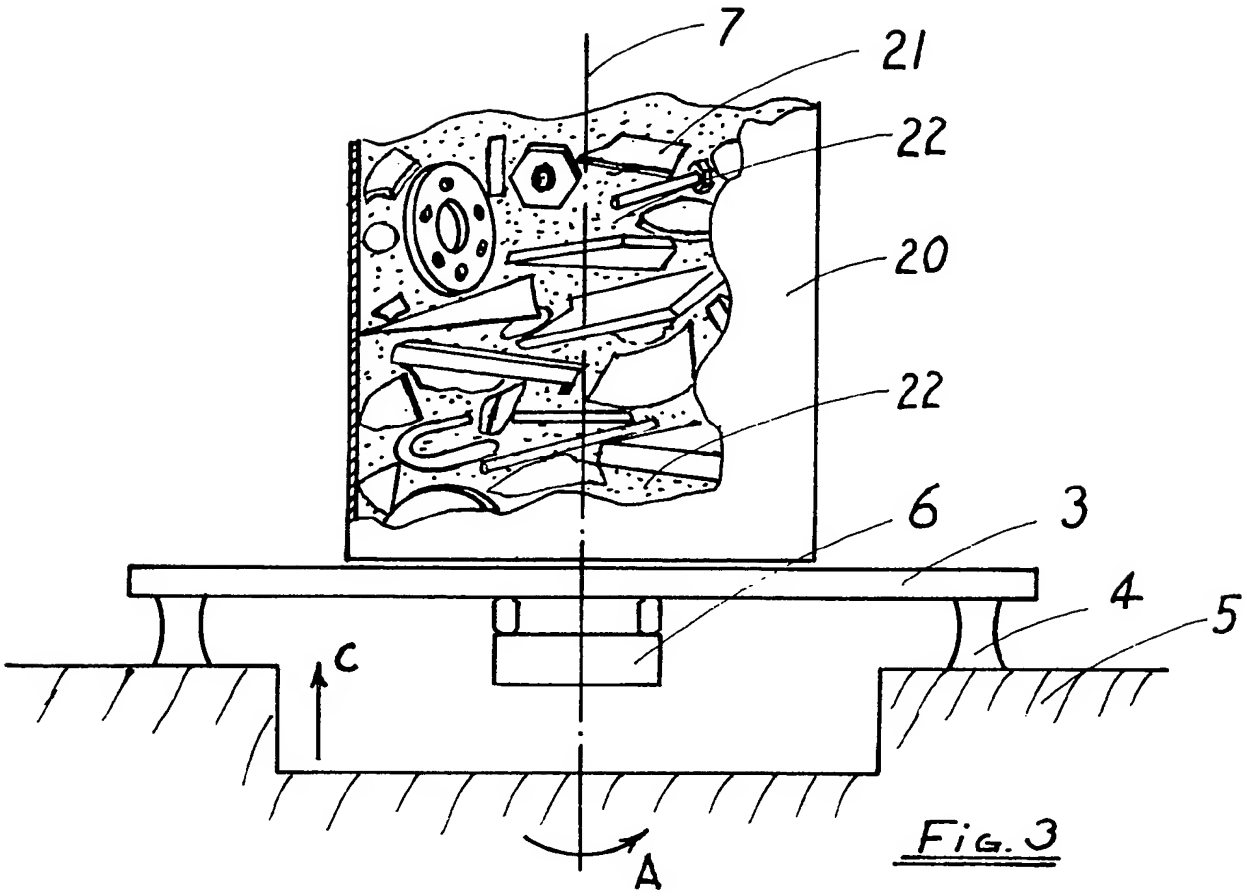

Fig. 3

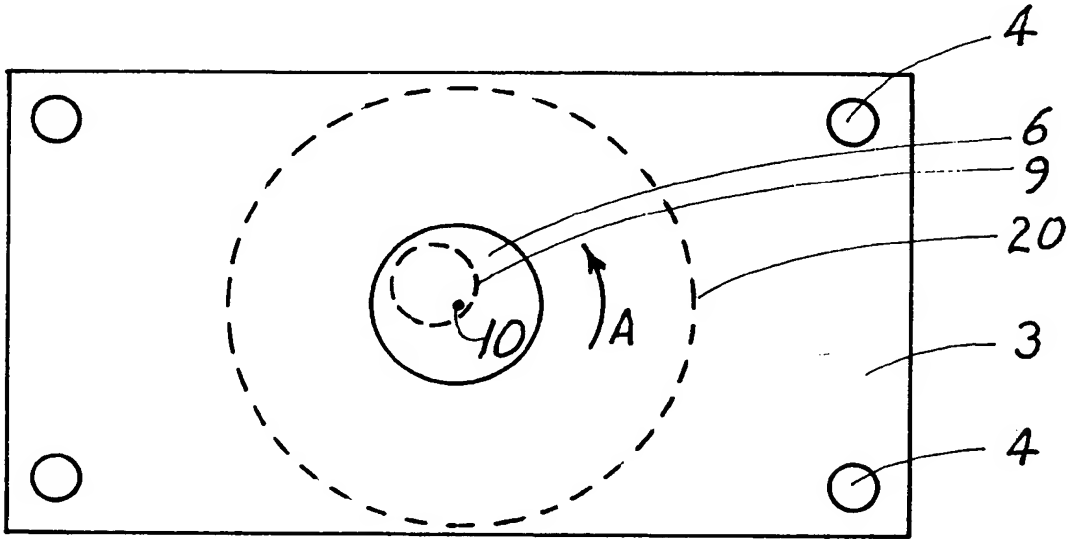

Fig. 4

SPECIFICATION

Filling interstices between pieces of material

The invention relates to a method of filling the interstices between a piece or pieces of material in a mould. The pieces may be irregular-shaped aggregate or particularly nuclear or toxic industrial waste.

When a cementitious slurry is being cast in the mould or container, containing pieces of irregular-shaped material such as aggregate it is frequently difficult to ensure that all voids in the mould or container are filled. If all voids are not filled the result is a finished article of cementitious material of inferior strength and porosity and/or form.

This difficulty is particularly apparent in the disposal of nuclear or toxic industrial waste. Usually the toxic or industrial waste is in the form of pieces of generally irregular-shaped material such as the fins of heat exchange tubes which are loaded into a container, usually a drum of steel material. Because of the variation in the size of the pieces and their generally irregular shape voids or interstices are left between the pieces.

Thus, the drum containing the pieces is generally unbalanced. This, it will be appreciated, could have disastrous consequences if the drum were to become dislodged and break open releasing contaminated material. In addition, if the waste is disposed of by burying the drum or stored above ground level or beneath the sea whether encapsulated in an outer layer of concrete or not, there is a risk that the radioactive or toxic elements of the waste may be leached out of the drum by entry of water.

To try and overcome these difficulties various attempts have been made to fill the interstices between the pieces of waste material with various materials to form a solid block however, such methods are not satisfactory in that voids or interstices are still left unfilled in the drum. Vibration techniques have been employed using conventional concrete vibrating techniques with a vibratory motion directed along the axis of the drum and a fixed frequency of vibration. This is unsatisfactory in that all the voids are not filled and also the energy requirement for such vibration is high since a large mass of material must be lifted at each stroke of vibration.

One method to try and achieve filling of the interstices involves the use of a very fluid cement paste however, this leads to material of low density between the pieces of waste material and consequent weakness.

Similar comments regarding known vibration techniques also apply to filling void between pieces of other types of material such as irregular-shaped pieces of stone aggregate.

There is therefore, a need for an improved method of filling the interstices between a piece or pieces of material in a mould. There is particularly a need for a method of filling the interstices between pieces of nuclear toxic industrial waste material in a container as well as an apparatus for carrying out these methods.

This invention is directed towards providing such methods and apparatus.

According to one aspect of the invention there is provided a method of filling the interstices between a piece or pieces of material in a mould comprising the steps of introducing cementitious mixture into the mould, and vibrating the mixture by a vibratory motion about a substantially vertical axis to substantially fill the interstices between the pieces of material.

Preferably the cementitious mixture is vibrated at a frequency at or close to the harmonic frequency of the mixture.

Usually the vertical axis of the vibrations coincides with the axis of the mould.

In one embodiment of this aspect of the invention the vibratory motion is a rotational motion.

In another embodiment of the invention the vibratory motion is an oscillating motion.

Preferably the oscillating motion describes an arc in a horizontal plane.

Typically the length of the arc of oscillation is dependent on the mass of the cementitious mixture.

Advantageously the vibrations are developed by an eccentric weight vibrator adapted for rotation or oscillation about a substantially vertical axis.

In one embodiment of the invention the pieces of material are pieces of irregular-shaped aggregate having interstices therebetween. In another embodiment of the invention the pieces of material are pieces of nuclear or toxic industrial waste. The pieces of material in the mould may be vibrated prior to introducing the cementitious mixture.

According to another aspect the invention provides a method of filling interstices between a piece or pieces of nuclear or toxic industrial waste material in a container comprising the steps of:—

introducing a cementitious mixture into the container, and vibrating the mixture by a vibratory motion about a substantially vertical axis to substantially fill the interstices between the pieces of nuclear or toxic industrial waste.

Preferably the cementitious mixture is vibrated at a frequency at or close to the harmonic frequency of the mixture.

Typically the vertical axis of the vibrations coincides with the axis of the container.

In one embodiment of this aspect of the invention the vibratory motion is a rotational motion.

In another embodiment of this aspect of the invention the vibratory motion is an oscillating motion.

Preferably the oscillating motion describes an arc in a horizontal plane.

Typically the length of the arc of oscillation is dependent on the mass of the cementitious mixture.

In another embodiment of this aspect of the invention the vibrations are developed by an eccentric weight vibrator adapted for rotation or

oscillation about a substantially vertical axis.

Preferably the container is a drum. The pieces of nuclear or toxic industrial waste may be vibrated prior to introducing the cementitious mixture.

The invention also provides an apparatus for performing the method of the invention including a table vibrator having an eccentric weight, the weight being adapted for rotation or oscillation about a substantially vertical axis. Preferably, the eccentric weight is movable at variable speeds.

The invention will be more clearly understood from the following description thereof given by way of example only with reference to the accompanying drawings in which:—

Fig. 1 is a partly sectional front elevational view of an apparatus according to the invention in this case used for filling the interstices between pieces of aggregate material in a mould.

Fig. 2 is an underneath plan view in the direction of the arrow B of the apparatus of Fig. 1,

Fig. 3 is a partly sectional front elevational view of an apparatus according to the invention in this case for use in filling the interstices between pieces of nuclear waste in a container, and

Fig. 4 is an underneath plan view in the direction of the arrow C of the apparatus of Fig. 3.

Referring to the drawings and initially to Figs. 1 and 2 thereof there is illustrated apparatus indicated generally by the reference numeral 1 for vibrating a mould, in this embodiment of the invention, a box-shaped mould 2 containing pieces of irregular-shaped aggregate 9 having interstices 9a therebetween. The apparatus 1 comprises a vibrating table 3 for receiving the mould 2. The table 3 is mounted on rubber vibrating mounts 4 on a base member 5, portion of which is shown in the drawings.

An eccentric weight vibrator 6 diagrammatically illustrated in the drawings is mounted on the underside of the table 3. A hydraulic motor (not shown) drives an eccentric weight 8 in the vibrator 6 about a shaft 10 in the direction of the arrow A. The axis 7 of rotation defined by the shaft 10 of the weight is substantially vertical and perpendicular to a surface of the table 3. Accordingly, the vibratory motion developed by the vibrator 6 is either a rotational motion or an oscillating motion about a vertical axis 7 which in this case coincides with the vertical axis of symmetry of the mould 2.

In use, the mould 2 is mounted on the vibrating table with its axis coinciding with the axis 7 of the vibrator 6. The drum is then filled with aggregate 9 which is vibrated to lock the individual pieces of aggregate into position. A cementitious slurry is then introduced into the mould and the vibrator 6 activated. The speed of the hydraulic motor and hence the frequency of oscillation of the eccentric weight 8 is tuned by a control valve on the hydraulic motor to frequency at or near the natural, sympathetic or harmonic frequency of the cementitious mass.

It has been found that by vibrating the cementitious mass with vibrations that are at or near its harmonic frequency about a vertical axis the cementitious slurry is fluidised and the voids between the pieces of aggregate in the mould are filled. If necessary, during vibration, as the voids are filled, the mould is made up with additional cementitious slurry.

The vibratory motion developed by the eccentric weight 8 may be either a rotational motion about a vertical axis to describe a full circle in which case the vibrations are in a circular mode or the weight may be movable in an oscillating motion about a vertical axis through a range of arcs in a horizontal plane. In both cases the frequency of vibration is harmonised or synchronised with that of the cementitious mixture.

When the vibratory motion is a rotational motion the frequency of vibrations is harmonised to the cementitious mixture in the mould. The speed of rotation of the eccentric weight is related to the harmonic frequency of the material being moulded. For a larger mass of material the speed of rotation is increased.

In the case where the vibratory motion is an oscillating motion the arc of oscillation is related to the mass of material in the mould and the frequency of oscillation is related to the harmonic frequency of the material being moulded. For a larger mass of material the length of the arc of oscillation is increased.

One advantage of directing the vibratory motion about a substantially vertical axis is that a low power input is required for vibration. In previously used methods of vibration the motion was generally about a substantially horizontal axis with the attendant requirement of having to lift the container or mould containing the cementitious mixture up against gravity.

Because all the voids between individual pieces of aggregate are filled the finished article will have exceptionally high structural strength over and above articles of cementitious materials made by conventional techniques. In conventional mixing techniques the aggregate does not lock together to maximum efficiency because of the presence of the cement grout or slurry.

In addition, because the cementitious slurry is fluidised by the method used a lower water to cement ratio than has heretofore been possible may be used. This, it will be appreciated leads to a stronger finished article.

Referring to Figs. 3 and 4 there is illustrated an apparatus similar to that described above with reference to Figs. 1 and 2, like parts being assigned the same reference numerals. In this case a container in the form of a cylindrical drum 20 filled with irregular-shaped pieces 21 of nuclear or toxic industrial waste is mounted on the table 3 with its vertical axis coinciding with the axis 7 of the vibrator 6. Cementitious slurry 22 is then poured into the drum 20. The vibrator 6 is activated and the drum is vibrated at a frequency at or near the natural or harmonic frequency of the cementitious mass as described above. If desired the pieces of material may be vibrated to lock them in position

in the drum prior to the introduction of the cementitious material.

It has been found that by vibrating the cementitious mass with vibrations that are at or near its natural or harmonic frequency the cementitious slurry 22 flows between the pieces 21 of waste material to fill all the interstices between the pieces. The fact that the vibrations are directed about a vertical axis also greatly assists in filling all the interstices. In addition, if there is any liqud waste in the drum this is also taken up by the slurry.

It will be appreciated that the pieces of material may be of any size or shape and may range from a single large piece which substantially fills the container or mould in which case the voids or interstices to be filled are between parts of the piece and/or the container or mould walls, to swarf or dust particles.

One advantage of this aspect of the invention is that is seals or encapsulates all the pieces of waste material into fixed positions in the drum leading to a far more stable drum that has theretofore been possible. In addition, because all the interstices are filled there is a reduced risk of any waste material being leached out of the drum when disposed of underground or at sea.

The pieces of material may be vibrated before the cementitious mixture is introduced so that a large proportion of the volume of the mould or container may be filled with the pieces. Using this technique it has been possible to achieve a 70% filling of the mould or container with pieces of material.

Similar comments and advantages as given above in relation to the method and apparatus described with reference to Figs. 1 and 2 also apply to this method and apparatus described with reference to Figs. 3 and 4 and vice versa.

While our experiments to date have been conducted using conventional Portland cement mixtures it is envisaged that the method may be applied to other cementitious materials. Accordingly, the term cementitious material as used in this specification refers to any suitable settable binding material such as gypsum, plaster, asphalt, resinous substances, plastics such as G.R.P. as well as conventional Portland cement and the like.

It will be appreciated that any suitable vibrating mounts may be used for table 3 for example, springs or an air cushion.

It will also be appreciated that the vibratory motion may be developed in any suitable manner such as already described or by a servo valve operated reciprocating ram.

It will further be appreciated that the method of the invention may be employed for filling the interstices between pieces of any type of material with a cementitious mixture.

CLAIMS

1. A method of filling the interstices between a piece or pieces of material in a mould comprising the steps of introducing cementitious mixture into the mould, and vibrating the mixture by a vibratory motion about a substantially vertical axis to substantially fill the interstices between the pieces of material.

2. A method as claimed in claim 1 in which the cementitious mixture is vibrated at a frequency at or close to the harmonic frequency of the mixture.

3. A method as claimed in claim 1 or 2 in which the vertical axis of the vibrations coincides with the axis of the mould.

4. A method as claimed in any of claims 1 to 3 in which the vibratory motion is a rotational motion.

5. A method as claimed in any of claims 1 to 3 in which the vibratory motion is an oscillating motion.

6. A method as claimed in claim 5 in which the oscillating motion describes an arc in a horizontal plane.

7. A method as claimed in claim 6 in which the length of the arc of oscillation is dependent on the mass of the cementitious mixture.

8. A method as claimed in any of the preceding claims in which the vibrations are developed by an eccentric weight vibrator adapted for rotation or oscillation about a substantially vertical axis.

9. A method as claimed in any preceding claim in which the pieces of material are pieces of irregular-shaped aggregate having interstices therebetween.

10. A method as claimed in claim 9 in which the pieces of material are pieces of nuclear or toxic industrial waste.

11. A method as claimed in any preceding claim in which the pieces of material in the mould are vibrated prior to introducing the cementitious mixture.

12. A method of filling the interstices between a piece or pieces of nuclear or toxic industrial waste material in a container comprising the steps of:—

introducing a cementitious mixture into the container, and vibrating the mixture by a vibratory motion about a substantially vertical axis to substantially fill the interstices between the pieces of nuclear or toxic industrial waste.

13. A method as claimed in claim 12 in which the cementitious mixture is vibrated at a frequency at or close to the harmonic frequency of the mixture.

14. A method as claimed in claim 12 or 13 in which the vertical axis of the vibrations coincides with the axis of the mould.

15. A method as claimed in any of claims 12 to 14 in which the vibratory motion is a rotational motion.

16. A method as claimed in any of claims 12 to 14 in which the vibratory motion is an oscillating motion.

17. A method as claimed in claim 16 in which the oscillating motion describes an arc in a horizontal plane.

18. A method as claimed in claim 17 in which the length of the arc of oscillation is dependent on the mass of the cementitious mixture.

19. A method as claimed in any of claims 12 to 18 in which the vibrations are developed by an eccentric weight vibrator for rotation or oscillation about a substantially vertical axis.

20. A method as claimed in any of claims 12 to 19 in which the container is a drum.

21. A method as claimed in any of claims 12 to 20 in which the pieces of nuclear or toxic industrial waste are vibrated prior to introducing the cementitious mixture.

22. Apparatus for performing the method of any of claims 1 to 11 or 12 to 21 including a table vibrator having an eccentric weight, the weight being adapted for rotation or oscillation about a substantially vertical axis.

23. Apparatus as claimed in claim 22 in which the eccentric weight is rotatable at variable speeds.

24. An article of cementitious material whenever prepared by a method as claimed in any of claims 1 to 12.

25. A container containing a piece or pieces of nuclear or industrial toxic waste in which interstices between the pieces are filled with a cementitious material by a method as claimed in any of claims 12 to 21.

26. A method of filling interstices between a piece or pieces material in a mould substantially as hereinbefore described with reference to and as illustrated in Figs. 1 to 4 of the accompanying drawings.

27. A method for filling interstices between a piece or pieces of nuclear or toxic industrial waste material in a container substantially as hereinbefore described with reference to and as illustrated in Figs. 3 and 4 of the accompanying drawings.

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